Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of the claims in the application:

Listing of Claims:

1. (Original) A method for writing a master image on a substrate, comprising:

dividing the master image into a matrix of frames, each frame comprising an array of pixels defining a respective frame image in a respective frame position within the master image;

scanning an electron beam in a raster pattern over the substrate; and

shaping the electron beam responsively to the respective frame image of each of the frames as the electron beam is scanned over the respective frame position on the substrate, so that in each frame, the electron beam simultaneously writes a multiplicity of the pixels onto the substrate.

2. (Original) The method according to claim 1, wherein each of the pixels has a respective pixel value, and wherein shaping the electron beam comprises writing all the pixels having the same pixel value in the respective frame image substantially simultaneously.

3. (Original) The method according to claim 2, wherein writing all the pixels comprises writing all the pixels in the respective frame image substantially simultaneously.

4. (Original) The method according to claim 1, wherein shaping the electron beam comprises writing all the pixels in each frame before scanning the electron beam to a successive frame in the raster pattern.

5. (Original) The method according to claim 1, wherein shaping the electron beam comprises focusing the electron beam onto the substrate so that at each position in the scan, the focused electron beam covers an area of a single frame.

6. (Original) The method according to claim 1, wherein scanning the electron beam comprises:

mechanically scanning the substrate along a primary scan direction; and

electrically scanning the electron beam in a secondary scan direction, transverse to the primary scan direction.

7. (Original) The method according to claim 6, wherein mechanically scanning the substrate comprises moving the substrate in the primary scan direction substantially continuously, and wherein electrically scanning the electron beam comprises electrically shifting the electron beam in the primary scan direction so as to compensate for motion of the substrate.

8. (Original) The method according to claim 6, wherein electrically scanning the electron beam comprises scanning the electron beam in the secondary scan direction in steps corresponding to the frames in a row of the matrix.

9. (Original) The method according to claim 1, wherein shaping the electron beam comprises:

dividing the electron beam into multiple beamlets; and

selectively blocking the beamlets responsively to the respective frame image of each of the frames.

10. (Original) The method according to claim 9, wherein each of the pixels has a respective pixel value, and wherein selectively blocking the beamlets comprises controlling a duration of blocking each of the beamlets responsively to the respective pixel value.

11. (Original) The method according to claim 9, wherein selectively blocking the beamlets comprises selectively deflecting the beamlets so that the deflected beamlets do not impinge on the substrate.

12. (Original) The method according to claim 11, wherein selectively deflecting the beamlets comprises directing each of the beamlets through a respective aperture among a plurality of apertures in a multi-blanker array, and applying a deflecting field in the respective aperture.

13. (Original) The method according to claim 12, wherein the multi-blanker array comprises a semiconductor substrate, through which the apertures are etched, having electrodes formed thereon for applying the deflecting field.

14. (Original) The method according to claim 9, wherein scanning the electron beam comprises applying a controlled deflection to the beamlets that are not blocked.

15. (Original) The method according to claim 9, wherein shaping the electron beam further comprises focusing the beamlets so as to demagnify the frame image formed by the beamlets that impinge on the substrate.

16. (Original) The method according to claim 15, wherein focusing the beamlets comprises forming the frame image on the substrate with a pixel size approximately in the range of 25 to 35 nm.

17. (Original) The method according to claim 1, wherein shaping the electron beam comprises:

modulating a beam of optical radiation responsively to the respective frame image of each of the frames; and

converting the modulated beam of optical radiation into the shaped electron beam.

18. (Original) The method according to claim 17, wherein converting the modulated beam of optical radiation comprises directing the modulated beam of optical radiation to impinge on a photocathode, so that the photocathode emits electrons responsively to the optical radiation, and wherein shaping the electron beam further comprises accelerating the electrons emitted by the photocathode toward the substrate.

19. (Original) The method according to claim 18, wherein scanning the electron beam comprises applying a controlled deflection to the accelerated electrons.

20. (Original) The method according to claim 18, wherein the photocathode is contained in an evacuated enclosure, and wherein accelerating the electrons comprises causing the electrons to exit from the enclosure through a membrane.

21. (Original) The method according to claim 18, wherein directing the modulated beam of optical radiation comprises focusing the modulated beam of optical radiation so as to form a demagnified image on the cathode, and wherein accelerating the electrons comprises focusing the electrons that impinge on the substrate so as to further demagnify the demagnified image.

22. (Original) The method according to claim 21, wherein modulating the beam of optical radiation comprises creating an optical image having a first pixel size, and wherein focusing the electrons that impinge on the substrate comprises forming an electron image having a second pixel size that is less than about 1/100 of the first pixel size.

23. (Original) The method according to claim 22, wherein the second pixel size is less than about 1/400 of the first pixel size.

24. (Original) The method according to claim 21, wherein focusing the electrons that impinge on the substrate comprises forming an electron image having a pixel size approximately in the range of 25 to 35 nm.

25. (Original) The method according to claim 17, wherein modulating the beam of optical radiation comprises directing the beam of optical radiation to impinge on spatial light modulator (SLM) comprising at least one array of micromirrors, and controlling respective orientations of the micromirrors responsively to the respective frame image.

26. (Original) The method according to claim 25, wherein each of the micromirrors corresponds to a pixel in the respective frame image and has an "on" position and an "off" position, and wherein controlling the respective orientations comprises setting a respective time during which each of the micromirrors is to be in the "on" position responsively to the corresponding pixel in the respective frame image.

27. (Original) The method according to claim 26, wherein setting the respective time comprises controlling a length of time during which each of the micromirrors is to be in the "on" position responsively to a gray-scale pixel value of the corresponding pixel.

28. (Original) The method according to claim 26, wherein directing the beam of optical radiation comprises varying an intensity of the beam of optical radiation so that the intensity has different values in a plurality of different time slots, and wherein setting the respective time comprises selecting the time slots during which each of the micromirrors is to be in the "on" position responsively to a gray-scale pixel value of the corresponding pixel.

29. (Original) The method according to claim 25, wherein the at least one array of micromirrors comprises a plurality of arrays of micromirrors, which are aligned in mutual registration such that each of the micromirrors in each of the arrays corresponds to a pixel in the respective frame image and has an "on" position and an "off" position, and

wherein directing the beam of optical radiation comprises directing at least a portion of the beam of optical radiation to impinge on each of the plurality of the arrays so that the arrays of micromirrors create respective partial frame images having respective sets of intensity levels, and combining the partial frame images to produce the frame image.

30. (Original) The method according to claim 29, wherein directing at least the portion of the beam of optical radiation comprises directing at least the portion of the beam to impinge on the arrays in succession, so that the partial frame images are created sequentially and not simultaneously.

31. (Original) The method according to claim 1, wherein dividing the master image comprises arranging the frames so that each frame comprises an overlap region in which the frame overlaps one or more other frames adjacent thereto in the matrix, and modifying the frame images in the overlap region so as to avoid discontinuities in features written on the substrate due to imperfect registration between the frames.

32. (Original) The method according to claim 31, wherein modifying the frame images comprises:

identifying a feature of the master image in the overlap region between first and second frames in the matrix;

if the feature extends outside the overlap region into the first frame but not into the second frame, assigning the feature to be written in the first frame but not in the second frame; and

if the feature extends outside the overlap region into both the first and second frames, assigning the feature to be written in both the first and second frames while blending a portion of the feature in the overlap region.

33. (Original) The method according to claim 1, wherein shaping the electron beam comprises:

shaping the electron beam responsively to a known reference pattern, so as to write a reference image on the substrate;

comparing the reference image to the reference pattern so as to map a distortion of the pattern; and

modifying the respective frame image responsively to the mapped distortion, thereby reducing the distortion in the frame image.

34. (Original) The method according to claim 1, wherein the substrate comprises a semiconductor wafer, and the master image comprises a circuit pattern, and wherein scanning and shaping the electron beam comprises writing the circuit pattern on the wafer.

35.- 51. (Cancelled)

52. (Original) Apparatus for writing a master image on a substrate, comprising:

a controller, which is adapted to divide the master image into a matrix of frames, each frame comprising an array of pixels defining a respective frame image in a respective frame position within the master image;

a translation device, which is adapted to cause an electron beam to scan over the substrate in a primary scan direction;

electron optics, which are adapted to scan the electron beam in a secondary scan direction, transverse to the primary scan direction, so that the electron beam is scanned in a raster pattern over the substrate; and

an electron beam generator, which is adapted to generate and shape the electron beam responsively to the respective frame image of each of the frames as the electron beam is scanned over the respective frame position on the substrate, so that in each frame, the electron beam simultaneously writes a multiplicity of the pixels onto the substrate.

53. (Original) The apparatus according to claim 52, wherein each of the pixels has a respective pixel value, and wherein the electron beam generator is adapted to write all the pixels having the same pixel value in the respective frame image substantially simultaneously.

54. (Original) The apparatus according to claim 53, wherein the electron beam generator is adapted to write all the pixels in the respective frame image substantially simultaneously.

55. (Original) The apparatus according to claim 52, wherein the electron beam generator is adapted to write all the pixels in each frame before the electron optics scan the electron beam to a successive frame in the raster pattern.

56. (Original) The apparatus according to claim 52, wherein the electron optics are adapted to focus the electron beam onto the substrate so that at each position in the scan, the focused electron beam covers an area of a single frame.

57. (Original) The apparatus according to claim 52, wherein the translation device comprises a translation stage, which is adapted to translate the substrate along the primary scan direction.

58. (Original) The apparatus according to claim 57, wherein the translation stage is adapted to move the substrate in the primary scan direction substantially continuously, and wherein the electron optics are adapted to electrically deflect the electron beam in the primary scan direction so as to compensate for motion of the substrate.

59. (Original) The apparatus according to claim 57, wherein the electron optics are adapted to scan the electron beam in the secondary scan direction in steps corresponding to the frames in a row of the matrix.

60. (Original) The apparatus according to claim 52, wherein the electron beam generator comprises:

a multi-lens array, which is adapted to divide the electron beam into multiple beamlets; and

a multi-beam blanker, which is aligned to selectively block the beamlets responsively to the respective frame image of each of the frames.

61. (Original) The apparatus according to claim 60, wherein each of the pixels has a respective pixel value, and wherein the multi-beam blanker is adapted to control a duration of blocking each of the beamlets responsively to the respective pixel value.

62. (Original) The apparatus according to claim 60, wherein the multi-beam blanker is adapted to selectively deflect the beamlets so that the deflected beamlets do not impinge on the substrate.

63. (Original) The apparatus according to claim 62, wherein the multi-beam blanker comprises:

a plurality of apertures, which are aligned so that each of the beamlets passes through a respective aperture among the plurality of apertures; and

electrodes, which are respectively associated with each of the apertures, and are coupled to apply a deflecting field in the respective aperture.

64. (Original) The apparatus according to claim 62, wherein the multi-blanker array comprises a semiconductor substrate, through which the apertures are etched, and on which the electrodes are formed in proximity to the respective apertures.

65. (Original) The apparatus according to claim 60, wherein the electron optics are adapted to scan the electron beam by applying a controlled deflection to the beamlets that are not blocked.

66. (Original) The apparatus according to claim 60, wherein the electron optics comprise an objective, which is adapted to focus the beamlets so as to demagnify the frame image formed by the beamlets that impinge on the substrate.

67. (Original) The apparatus according to claim 66, wherein the objective is adapted to focus the frame image on the substrate to a pixel size approximately in the range of 25 to 35 nm.

68. (Original) The apparatus according to claim 52, wherein the electron beam generator comprises:

an optics module, which is adapted to modulate a beam of optical radiation responsively to the respective frame image of each of the frames; and

a photocathode, on which the modulated beam of optical radiation is incident, and which is adapted to emit electrons responsively to the optical radiation, so as to generate and shape the electron beam.

69. (Original) The apparatus according to claim 68, wherein the electron optics are adapted to accelerate the electrons emitted by the photocathode toward the substrate.

70. (Original) The apparatus according to claim 69, wherein the electron optics are adapted to scan the electron beam by applying a controlled deflection to the accelerated electrons.

71. (Original) The apparatus according to claim 69, and comprising an evacuated enclosure containing the photocathode, the enclosure comprising an optical window adapted for passage of the optical radiation therethrough and a membrane adapted for passage of the electron beam therethrough.

72. (Original) The apparatus according to claim 68, wherein the optics module comprises an optical objective, which is adapted to focus the modulated beam of optical radiation so as to form a demagnified image on the cathode, and wherein the electron optics comprise an electron objective, which is adapted to focus the electrons that impinge on the substrate so as to further demagnify the demagnified image.

73. (Original) The apparatus according to claim 72, wherein the objective is adapted to form an optical image having a first pixel size, and wherein the electron objective is adapted to form an electron image having a second pixel size that is less than about 1/100 of the first pixel size.

74. (Original) The apparatus according to claim 73, wherein the second pixel size is less than about 1/400 of the first pixel size.

75. (Original) The apparatus according to claim 72, wherein the electron optics comprise an electron objective, which is adapted to focus the electrons that impinge on the substrate so as to form an electron image having a pixel size approximately in the range of 25 to 35 nm.

76. (Original) The apparatus according to claim 68, wherein the optics module comprises a spatial light modulator (SLM) comprising at least one array of micromirrors, on which the beam of optical radiation is incident, and wherein the controller is coupled to cause the SLM to modulate the beam of optical radiation by controlling respective orientations of the micromirrors responsively to the respective frame image.

77. (Original) The apparatus according to claim 76, wherein each of the micromirrors corresponds to a pixel in the respective frame image and has an "on" position and an "off" position, and wherein the controller is adapted to set a respective time during which each of the micromirrors is to be in the "on" position responsively to the corresponding pixel in the respective frame image.

78. (Original) The apparatus according to claim 77, wherein the controller is adapted to control a length of time during which each of the micromirrors is to be in the "on" position responsively to a gray-scale pixel value of the corresponding pixel.

79. (Original) The apparatus according to claim 77, wherein the optics module comprises a beam source, which is adapted to generate the beam of optical radiation while varying an intensity of the optical radiation so that the intensity has different values in a plurality of different time slots, and wherein the controller is adapted to select the time slots during which each of the micromirrors is to be in the "on" position responsively to a gray-scale pixel value of the corresponding pixel.

80. (Original) The apparatus according to claim 76, wherein the at least one array of micromirrors comprises a plurality of arrays of micromirrors, which are aligned in mutual registration such that each of the micromirrors in each of the arrays corresponds to a pixel in the respective frame image and has an "on" position and an "off" position, and

wherein the optics module is adapted to direct at least a portion of the beam of optical radiation to impinge on each of the plurality of the arrays so that the arrays of micromirrors create respective partial frame images having respective sets of intensity levels, and comprises a beam combiner, which is adapted to combine the partial frame images to produce the frame image.

81. (Original) The apparatus according to claim 80, wherein the optics module is adapted to direct at least the portion of the beam of optical radiation to impinge on the arrays in succession, so that the partial frame images are created sequentially and not simultaneously.

82. (Original) The apparatus according to claim 52, wherein the controller is adapted to divide the master image into the frames so that each frame comprises an overlap region in which the frame overlaps one or more other frames adjacent thereto in the matrix, and wherein the controller is adapted to modify the frame images in the overlap region so as to avoid discontinuities in features written on the substrate due to imperfect registration between the frames.

83. (Original) The apparatus according to claim 82, wherein the controller is adapted to identify a feature of the master image in the overlap region between first and second frames in the matrix, and to modify the frame images of the first and second frames so that if the feature extends outside the overlap region into the first frame but not into the second frame, the feature is assigned to be written in the first frame but not in the second frame, whereas if the feature extends outside the overlap region into both the first and second frames, the feature is assigned to be written in both the first and second frames while blending a portion of the feature in the overlap region.

84. (Original) The apparatus according to claim 52, wherein the controller is adapted to modify the respective frame image of each of the frames responsively to a map of distortion created by shaping the electron beam responsively to a known reference pattern, so as to write a reference image on the substrate, and comparing the reference image to the reference pattern so as to map the distortion of the pattern.

85. (Original) The apparatus according to claim 52, wherein the substrate comprises a semiconductor wafer, and the master image comprises a circuit pattern, which is written by shaping and scanning the electron beam.

86.-102. (Cancelled) pattern, and wherein the radiation source is adapted to write the circuit pattern on the wafer.